IDENTIFICATION OF SINGLE UNITS IN MULTI-UNIT RECORDINGS FROM PERIPHERAL NERVES

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ABSTRACT

We are developing a computer-based method for identifying individual action potentials in multi-unit peripheral nerve recordings. Threshold level, sinusoidal stimuli are used to elicit phase-locked activity from single units. These action potentials are digitized, and a template is constructed using various waveform parameters. Once templates have been generated for all the units, the program is used in a sorting mode in which action potentials are detected and digitized, and parameter values are measured and compared to the template values. The output of the program is an indication of the 'instantaneous firing rate' of each identified unit as a function of time. In principle, the sorting could be done on-line in real-time.

INTRODUCTION

Our goal is to develop a computer-based method for acquiring information about the firing patterns of individual cells in multi-unit recordings from peripheral nerves. It is intended that information about somatosensory stimuli extracted from peripheral nerves with this method may be used to provide feedback control for functional electrical stimulation, or that it may be returned to the central nervous system via a synthetic link to restore sensation lost due to interruption of central pathways.

A variety of approaches have been used to separate single unit activity in multi-unit recordings [1], but few of these methods operate on-line and in real-time, which is necessary for the method to be incorporated into a feedback control system. The spike separation method we have developed classifies action potentials on the basis of their fit to templates made up of three amplitude parameters and one duration parameter. One benefit of using this method is that it could be implemented in real time [2].

A unique feature of our approach is that we have taken advantage of an intrinsic property of somatosensory receptors to simplify the task of template construction. Using a sinusoidal mechanical stimulus, it is possible to elicit phase-locked firing from mechanoreceptors [3, 4] By adjusting the frequency and intensity of the stimulus it is possible to activate a single afferent nerve fiber.

The operation of our program can be broken down into two stages. In the first stage, which is performed off-line and requires user interaction, a set of templates representing the individual units in the recording is built up. The second stage uses these templates to automatically digitize action potentials and associate them with templates. The program was written in C and assembly language.

METHODS

Multi-unit signals were recorded from the radial nerves of anesthetized cats with electrodes implanted inside single fascicles. Cutaneous mechanoreceptors innervated by nerve fibers contributing to the recorded signal were activated with both sinusoidal mechanical stimuli provided by a small vibrating probe driven by a sine wave generator and 'natural' stimuli such as brushing or squeezing the skin. The neural signal was stored on FM tape.

<u>DATA DIGITIZATION.</u> The occurrence of an action potential is detected by monitoring whether the neural signal voltage is greater than a user-specified trigger level. Once the trigger level is exceeded, the signal is digitized at a rate

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of 40.4 KHz for a period of time sufficient to contain the action potential waveform, and the digitized values are stored in an array in memory.

TEMPLATE CONSTRUCTION. The use of threshold sinusoidal stimuli makes it possible to selectively generate a set of sample action potentials from a single unit. For a given stimulus frequency, the action potentials from the unit occur at a fixed point in the stimulus cycle. To generate a template for the unit, action potentials are digitized and their timing with respect to the stimulus cycle is recorded. Those potentials occurring at a fixed phase relation to the stimulus are used to determine parameter values for the template. Parameters used include the maximum and minimum voltages of the waveform, the peak-to peak amplitude, and the sample number at which the signal becomes less than zero volts.

The parameter values for the unit action potentials can be displayed either in the form of a frequency histogram or as two-component scatter plots. Upper and lower limits for each of the parameter values are then selected by the user on the basis of these data.

CLASSIFICATION. Once templates for all identified units are generated, a second routine is used for spike classification. Action potentials are digitized and the time of occurrence is noted. Amplitude and duration parameters are determined for each digitized action potential and compared to each of the templates. The action potential is identified as coming from a given unit if the values of the four parameters for the waveform fit within the ranges of parameter values specified for the template for that unit. The instantaneous firing frequency for each unit is calculated from the time interval since the last potential occurred in the unit. If an action potential does not match any of the templates, the occurrence of a 'no match' is reported. In this case, no frequency is calculated.

RESULTS / DISCUSSION

The program classified single unit activity from recordings containing action potentials from up to four units. When the neural activity had been evoked with the use of sinusoidal mechanical stimuli, the instantaneous firing frequencies reported for the units were those expected for the frequency of the stimulus. The program was also able to classify single unit action potentials in multi-unit neural activity evoked by stimuli such as brushing or squeezing the skin.

Although our spike separation program does not currently operate in real time, real-time operation could be achieved by constructing a dedicated, hybrid analog/digital system for the sorting algorithm.

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